NUMERICAL MODELING OF HUMAN OCCUPANTS AND AUTOMOTIVE SAFETY

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With rapid advances in computing power, sophisticated numerical models of vehicles and crash dummies are routinely employed in the design and evaluation of new prototypes. Dummies are mechanical devices that could be simulated accurately. However, the lack of biofidelity associated with mechanical dummies is also reflected in dummy models. Even though the application of dummies and their numerical counterparts have greatly improved crash safety for subjects that are similar in sizes to these dummies in full frontal and lateral impacts, protection provided for other collision directions or for occupants of non-standard sizes is not fully effective. Numerical human surrogates simulating both genders and of different sizes can be used to study impacts from all directions and can offer the general population more protection than what is available now.

The development of such a surrogate requires comprehensive knowledge of human anatomy, the constitutive laws governing a large variety of human tissues, and injury thresholds. Additionally, response data at different loading rates, similar to real world crashes, are needed for model validation. This paper summarizes regional models of the human body, from head to foot, developed at Wayne State University (WSU) over the last decade [1-8]. In general, one of the strengths of these models is that they employ an accurate and detailed geometry of the body region, thus rendering it suitable for investigation of injury mechanisms. Some of these models are being used to improve vehicular seat and restraint system design.

The WSU brain model simulates all the essential substructures of the head and brain and has been validated against available intracranial pressure, ventricular pressure, and relative displacement between the skull and the brain [1, 8]. It is being used to evaluate the efficacy of current helmet designs. The neck model, which includes all seven cervical vertebrae, intervertebral discs, and 15 pairs of passive muscles, has been validated against data obtained in vertical head drop and rearend impact tests [7]. It has been applied to a study of neck responses when interacting with an airbag. The chest model includes descriptions of the rib cage, heart, lung, and major blood vessels. It has been validated against pendulum impact data from frontal and lateral impacts as well as against lateral sled test data when whole body cadavers slid into a rigid or padded wall [4, 6]. The model has been used to determine the mechanism of aortic rupture as well as injury to the upper arm interacting with a side airbag. The abdominal model includes detail descriptions of vital solid organs and major blood vessels while other hollow organs were lumped into three "body bags" to transfer loads [5]. This model could be used to simulate the interaction between the seat belt and the abdomen. The lower extremity model includes all main anatomical structures from the pelvis to foot [2, 3]. It has been validated against 21 different sets of experimental data and has been applied to study dynamic interactions between the knee and a knee bolster.

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